COMBINED DISC AND SHROUD FOR DUAL CYCLONIC CLEANING APPARATUS

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates to a combined disc and shroud for a dual cyclonic cleaning apparatus. In particular the present invention relates to an apparatus which has an improved means for retaining dirt in an outer cyclonic container while allowing clean air to pass into a frusto-conically shaped inner cyclone.

(2) Prior Art

Cyclonic vacuum cleaning apparatus are shown in my U.S. Pat. Nos. 4,573,236, 4,593,429, 4,571,772 and 4,643,748. My U.S. Pat. No. 4,643,748 describes a dual cyclonic cleaning apparatus wherein a disc is mounted on the outside of a frusto-conically shaped inner cyclone in order to retain dirt in a first cyclonic cleaner. A separate shroud is provided for inlet of air into the second cyclone, including a moveable collar to dislodge accumulated dirt. A perforated inlet to the shroud has also been used on a cyclonic vacuum cleaner marketed in Japan in place of the collar. In these cleaners, the shroud and disc are separate from each other although both function to retain dirt particularly fibrous dirt in the container. The separate disc and shroud work well; however, there was a need for an improved design providing better separation of dirt in the outer cyclone than was achieved by the earlier apparatus.

It was found that by experimenting with the position of the holes and their location it was possible to reduce the blocking of the holes by fibrous particles.

OBJECTS

It is therefore an object of the present invention to provide an improved cleaning apparatus wherein the shroud and disc are combined together for mounting on the outside of the inner cyclone. Further, it is an object of the present invention to provide a combined disc and shroud which is simple and inexpensive to construct and easy to clean of fibrous matter, and which at the same time prevents escape from the outer cyclone of fibrous matter (or in the case of over-filling by the operator of all matter) and at the same time prevents or discourages the blocking of the holes by fibrous particles. These and other objects will become increasingly apparent to those skilled in the art and by reference to the drawings.

IN THE DRAWINGS

FIG. 1 is a front cross-sectional view of the preferred upright vacuum cleaning apparatus of the present invention, particularly showing the mounting of the combined shroud and disc on the outside of the inner cyclone.

FIG. 2 is a perspective view of the combined disc and shroud.

FIG. 3 is a cross-sectional view along line 3—3 of FIG. 2 showing the perforations 30*f*.

FIG. 4 is a cross-sectional view along line 5—5 of FIG. 1 showing the tangential entry into the inner cyclone 12.

GENERAL DESCRIPTION

The present invention relates to a cleaning apparatus including an outer container comprising a bottom and a sidewall extending to and meeting the bottom, the sidewall having an interior surface, a dirty air inlet which is oriented for supplying dirt laden air into the container tangentially to the interior surface of the outer container which has a circular cross-section and an air outlet from the container; a circular cross-sectioned cyclone having a longitudinal axis mounted inside the container, the cyclone comprising a cyclone air inlet at an upper end having a first diameter of the cyclone in air communication with the air outlet of the container, an interior dirt rotational surface of frusto-conical shape for receiving an airflow from the air inlet and for maintaining its velocity to a cone opening smaller in diameter than the diameter of the upper end of the cyclone, the air inlet being oriented for supplying air tangentially to the surface, an outer surface of frusto-conical shape, and a cyclone air outlet communicating with the interior of the cyclone adjacent the upper end of the cyclone; a dirt receiving and collecting chamber extending from the cone opening; and means for generating an air flow which passes sequentially through the dirty air inlet, the container, the cyclone air inlet, the cyclone, the receiving chamber and the cyclone air outlet, the air flow rotating around the frusto-conical interior surface of the cyclone and depositing the dirt in the receiving chamber the improvement which comprises:

a shroud means mounted on and around outer surface of the cyclone and having opposed ends along the longitudinal axis and providing for outlet air from the container into the air inlet to the cyclone wherein the shroud means is mounted below the air inlet to the cyclone at one of the opposed ends of the shroud means and extends along (preferably substantially parallel to) the outer surface to a position intermediate to the cone opening and the air inlet, wherein the shroud means contacts the outer surface of the cyclone for closure (which does not necessarily have to seal to the outer cyclone) at the other of the ends, and wherein the shroud means has perforations adjacent to the intermediate position for the outlet of air; and

disc means provided on the shroud means at the position intermediate the cone opening and the air inlet to the cyclone and around the axis of the cyclone with a space between the interior surface of the container and the disc means for passage of air, wherein the disc means aids in dirt removal in the first container. The disc particularly holds fluff down in the container.

SPECIFIC DESCRIPTION

FIGS. 1 and 4 show a cleaning apparatus 10, such as in an upright vacuum cleaner, including an outer cyclone or container 11 and an inner cyclone 12. The container 11 and cyclone 12 are relatively long and slender along the longitudinal axis a—a. The outer container 11 has a bottom 11*a* and a cylindrical inner surface 11*b* which extends from the bottom 11*a*. The container 11 is removable from an air-flow directing head 13. A flexible ring seal 13*a* engages the end surface 11*c* of the outer container 11. The head 13 includes a dirty air inlet passage 13*b* connected to a pipe 13*c* projecting downward from the head 13 into an inlet pipe 14 connected to an air inlet chamber 15 in cleaner casing 16. An outlet passage 13*d* is provided in the head 13 by conduit 13*e* leading to passage 13*f* connected to pipe 13*g* projecting into an outlet pipe 17 leading to air outlet chamber 18 in casing 16. The air could vent at the top of the head 13 (not shown). There are o-ring seals 13*i* on the outside of pipes 13*c* and 13*g*, respectively, sealing

with pipes 14 and 17, respectively. Motor pan 19 draws air from cleaner head 23 and blows it to chamber 15. The cleaner head 23 can pivot on the cleaner 10 and can also have a brush (not shown). A handle 24 is provided for moving the upright cleaner 10.

The cyclone 12 has a frusto-conical shape and an inner wall 12*a* leading to a cone opening 12*c* and an outer wall 12*b*. A portion of the cyclone 12 and the cone opening 12*c* projects into a receiving and collecting chamber 20 for collecting dirt from cyclone 12. The outer wall 12*b* of the inner cyclone 12 engages a tapered ring seal 21 mounted on one end of an elongated cylindrical portion 20*a* of the receiving chamber 15. The tapered seal 21 includes at least one concentric ring 21*a* which engage the outer wall 12*b* of the cyclone 12. The receiving chamber 20 is preferably integrally joined with a frusto-conical or outwardly tapered portion 20*b* which also serves as the bottom 11*a* of the container 11. A removable dish shaped member 22 covers the end of the tapered portion 15*b*. The sidewalls 22*a* are cylindrical.

A combined integral shroud and disc unit 30 is mounted intermediate the inlet 13*k* to the cyclone 12 and the cone opening 12*c* as particularly shown in FIG. 1. The unit 30 provides an outlet passage 13*h* from the container 11. The unit 30 includes a disc 30*a* which is preferably conically shaped with a larger downwardly tapered portion 30*b*, facing the bottom 11*a* of the container 11. The unit 30 is tapered with walls 30*c* preferably parallel to the outside 12*b* of the cyclone 12. The walls 30*c* end in a flange 30*d* which surrounds and encloses the inlet passage 13*k* to the inner cyclone 12. A lower portion 30*e* contacts the outside 12*b* of the cyclone 12 adjacent the disc 30*b*. Perforations 30*f* are provided around the wall 30*c* on about a lower one-third of the wall 30*c* adjacent the disc 30*b*. The disc preferably has a downwardly inclined angle alpha between about 97½ to 110° from the axis area or 7½ to 20° from a line perpendicular to the axis.

In operation, the fan unit 19 blows air into inlet chamber 15 through tube 14 into inlet 13*b* of the container 11. The air swirls down around the inner wall 11*b* of the container 11 and up along the outside of cylindrical portion 20*a* of receiver 20, moves along outer wall 12*b*, over disc 30*b*, through perforations 30*f* and up through passage 13*h* defined by shroud unit 30 and wall 12*b*. The air then moves into inlet passage 13*k* of had 13 and into the inner cyclone 12 wherein it moves around inner wall 12*a* and to cone opening 12*c* and then moves upward to outlet 13*d* in passage 13*e* and then exhausts to atmosphere or through tube 17 and chamber 18 to motor fan. The dirt collects on the bottom 11*a* of the container 11 and in the dish shaped member 22 as shown. Finer dirt collects primarily in the dish shaped member 22. The inlet chamber 15 is preferably connected to the cleaning head 23.

It has been found that having the perforations 30*f* immediately adjacent the disc 30*b* provides an advantage in separation. In the prior designs of U.S. Pat. No. 4,571,772, the shroud was remote from the disc, and thus allowed a greater chance of dirt escaping into the inner cyclone 12 and helps clogging of the holes by fibrous particles. Preferably the cross-sectional area of the perforations 30*f* exceeds the cross-sectional area of either the inlet passage 13*b* or outlet passage 13*k*.

It is intended that the foregoing description be only illustrative and that the present invention be limited only by the hereinafter appended claims.

I claim:

1. In a cleaning apparatus including an outer container comprising a bottom and a sidewall extending to and meeting the bottom, the sidewall having an interior surface, a dirty air inlet which is oriented for supplying dirt laden air into the container tangentially to the interior surface of the outer container which has a circular cross-section and an air outlet from the container; a circular cross-sectioned cyclone having a longitudinal axis mounted inside the container, the cyclone comprising a cyclone air inlet at an upper end having a first diameter of the cyclone in air communication with the air outlet of the container, an interior dirt rotational surface of frusto-conical shape for receiving an air flow from the air inlet and for maintaining its velocity to a cone opening smaller in diameter than the diameter of the upper end of the cyclone, the air inlet being oriented for supplying air tangentially to the surface, an outer surface of frusto-conical shape, and a cyclone air outlet communicating with the interior of the cyclone adjacent the upper end of the cyclone; a dirt receiving and collecting chamber extending from the cone opening; and means for generating an air flow which passes sequentially through the dirty air inlet, the container, the cyclone air inlet, the cyclone, the receiving chamber and the cyclone air outlet, the air flow rotating around the frusto-conical interior surface of the cyclone and depositing the dirt in the receiving chamber the improvement which comprises:

(a) a shroud means mounted on and around the outer surface of the cyclone and having opposed ends along the longitudinal axis and providing for outlet air from the container into the air inlet to the cyclone wherein the shroud means is mounted at one end below the air inlet to the cyclone and extends along the outer surface with the other end at a position intermediate to the cone opening and the air inlet to the cyclone, wherein the shroud means contacts the outer surface of the cyclone for closure at the other of the ends and wherein the shroud means has perforations adjacent to the position intermediate to the cone opening for the flow of air from the outer container to the cyclone inlet; and

(b) disc means provided on the shroud means at a lower longitudinal extent of the shroud means and the air inlet of the cyclone and around the axis of the cyclone with a space between the interior surface of the container and the disc means for passage of air, wherein the disc means aids in dirt removal in the first container by preventing some of the dirt from flowing into the air inlet to the cyclone.

2. The apparatus of claim 1 wherein the disc means is circular in cross-section around the longitudinal axis of the cyclone.

3. The apparatus of claim 1 wherein the disc means has a conical shape around the shroud means such that a larger portion of the conical shape faces towards the bottom of the container.

4. The apparatus of claim 3 wherein the conical shape when viewed as a cross-section of the shroud means and disc means through the longitudinal axis is at a downwardly inclined angle of about 7½ to, 20° from a line perpendicular to the longitudinal axis of the cyclone.

5. The apparatus of claim 1 wherein the perforations in the shroud means are circular and are provided around the circumferential extent of the shroud means

and cover about one-third of the shroud means above the disc means.

6. The apparatus of claim 1 wherein the shroud means has a flange around the longitudinal axis at the end adjacent the air inlet to the cyclone which is in close relationship to the outside of the cyclone so as to provide a chamber providing the inlet to the cyclone.

7. The apparatus of claim 1 wherein the disc means is positioned about one-third of the distance between the cone opening and the air inlet of the cyclone.

8. The apparatus of claim 1 wherein the dirt receiving and collecting chamber is mounted on the outer surface of the cyclone and has a conical portion adjacent the bottom of the container which tapers outward towards the sidewall and the bottom of the container.

9. The apparatus of claim 8 wherein the chamber has a cylindrical portion which extends from the outer surface of the cyclone to the conical portion which tapers outward from the cylindrical portion towards the sidewall and the bottom of the container.

10. The apparatus of claim 9 wherein the cylindrical portion has a diameter smaller than a diameter of the disc means.

11. The apparatus of claim 1 wherein the outer container has a substantially cylindrical sidewall.

12. The apparatus of claim 11 wherein the apparatus is a vacuum cleaner for household use, wherein the inlet to the container and the outlet from the cyclone include separate tubes mounted parallel to the axis adjacent the opposite sides of the container leading to the inlet and from the outlet and wherein the means for generating an air flow is mounted in a casing with a cleaning means which contacts a surface to be cleaned, wherein the means for generating an air flow draws air into the inlet to the container through one of the tubes and out the outlet from the cyclone through the other of the tubes to and through the casing.

13. The apparatus of claim 12 wherein the disc means is circular in cross-section around the longitudinal axis of the cyclone.

14. The apparatus of claim 12 wherein the disc means has a conical shape around the shroud means such that a larger portion of the conical slope faces towards the bottom of the container.

15. The apparatus of claim 14 wherein the conical shape when viewed in a cross-section of the shroud means and disc means through the longitudinal axis is at an angle of about 7½ and 20° to a line perpendicular to the longitudinal axis of the cyclone.

16. The apparatus of claim 12 wherein the perforations are circular and are provided around the circumferential extent of the shroud means and cover about one-third of the shroud means above the disc means.

17. The apparatus of claim 12 wherein the shroud means has a flange around the longitudinal axis at the end adjacent the inlet to the cyclone which is in close spaced relationship to the outside of the cyclone.

18. The apparatus of claim 12 wherein the disc means is positioned about one-third of the distance between the cone opening and the air inlet of the cyclone.

19. The apparatus of claim 12 wherein the dirt receiving and collecting chamber is mounted on the outer surface of the cyclone and has a conical portion adjacent the bottom of the container which tapers outward towards the sidewall and the bottom of the container.

20. The apparatus of claim 19 wherein the chamber has a cylindrical portion which extends from the outer surface of the cyclone to the conical portion which tapers outward from the cylindrical portion towards the sidewall and the bottom of the container.

21. The apparatus of claim 20 wherein the cylindrical portion has a diameter smaller than a diameter of the disc means.

22. The apparatus of claim 1 wherein the total cross-sectional area of all the perforations exceeds the cross-sectional area of each of the air inlet and the air outlet from the cyclone.

23. A shroud means for use in a cleaning apparatus including an outer container comprising a bottom and a sidewall extending to and meeting the bottom, the sidewall having an interior surface, a dirty air inlet which is oriented for supplying dirt laden air into the container tangentially to the interior surface of the outer container which has a circular cross-section and an air outlet from the container; a circular cross-sectioned cyclone having a longitudinal axis mounted inside the container, the cyclone comprising a cyclone air inlet at an upper end having a first diameter of the cyclone in air communication with the air outlet of the container, an interior dirt rotational surface of frusto-conical shape for receiving an air flow from the air inlet and for maintaining its velocity to a cone opening smaller in diameter than the diameter of the upper end of the cyclone, the air inlet being oriented for supplying air tangentially to the surface, an outer surface of frusto-conical shape, and a cyclone air outlet communicating with the interior of the cyclone adjacent the upper end of the cyclone; a dirt receiving and collecting chamber extending from the cone opening; and means for generating an air flow which passes sequentially through the dirty air inlet, the container, the cyclone air inlet, the cyclone, the receiving chamber and the cyclone air outlet, the air flow rotating around the frusto-conical interior surface of the cyclone and depositing the dirt in the receiving chamber the improvement which comprises:

(a) a shroud means to be mounted on and around the outer surface of the cyclone and having opposed ends along the longitudinal axis and providing for outlet air from the container into the air inlet to the cyclone wherein the shroud means is mounted at one end below the air inlet to the cyclone at one of the opposed ends of the shroud means and extends along the outer surface with the other end at a position intermediate to the cone opening and the air inlet to the cyclone, wherein the shroud means contacts the outer surface of the cyclone for closure at the other of the ends and wherein the shroud means has perforations adjacent to the position intermediate to the cone opening for the flow of air from the outer container to the cyclone inlet; and

(b) disc means provided on the shroud means at a lower longitudinal extent of the shroud means and the air inlet of the cyclone and around the axis of the cyclone with a space between the interior surface of the container and the disc means for passage of air, wherein the disc means aids in dirt removal in the first container by preventing some of the dirt from flowing into the air inlet to the cyclone.

24. The shroud means of claim 23 wherein the disc means is circular in cross-section around the longitudinal axis of the cyclone.

25. The shroud means of claim 23 wherein the disc means has a conical shape around the shroud means such that a larger portion of the conical shape faces towards the bottom of the container.

26. The shroud means of claim 25 wherein the conical shape when viewed as cross-section of the shroud means and disc means through the longitudinal axis is at a downwardly inclined angle of about 7½ to 20° from a line perpendicular to the longitudinal axis of the cyclone.

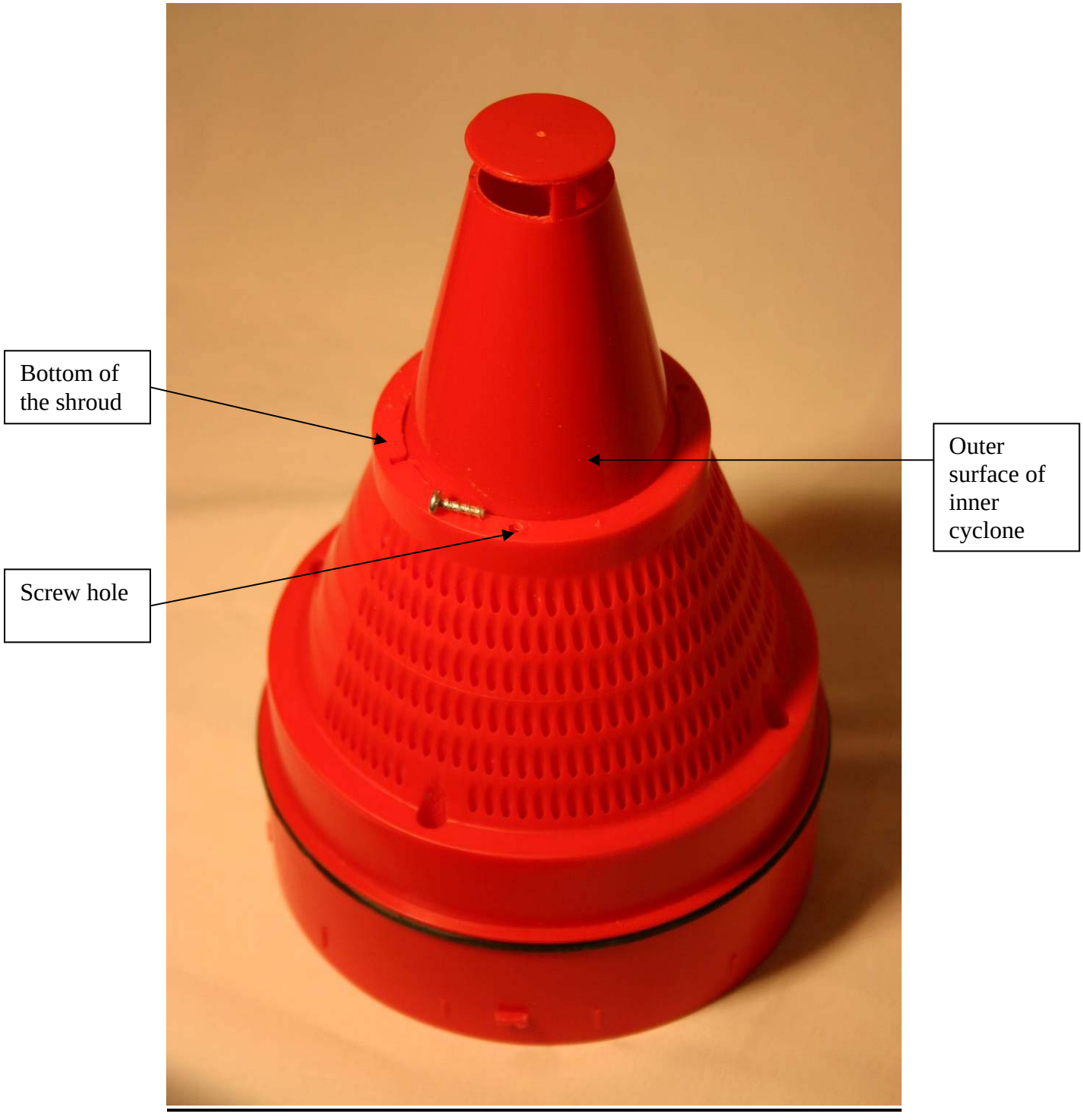
27. The shroud means of claim 23 wherein the perforations in the shroud means are circular and are provided around the circumferential extent of the shroud means and cover about one-third of the shroud means above the disc means.

28. The shroud means of claim 1 wherein the shroud means has a flange around the longitudinal axis at the end adjacent the air inlet to the cyclone which is in close relationship to the outside of the cyclone so as to provide a chamber providing the inlet to the cyclone.

* * * * *

Exhibit 24 – Photograph showing location of the shroud on the Hoover Fusion

Exhibit 25 – Photograph showing fixings at the bottom of the shroud means on the Hoover Fusion



Note – shroud means and disc are shown upside down, and the receiving chamber, disc means, and screws have been removed for clarity

Exhibit 26 – Copy of US Patent 5,858,038

US005858038A

United States Patent [19]

Dyson et al.

[11] Patent Number: 5,858,038

[45] Date of Patent: Jan. 12, 1999

[54] DUST SEPARATION APPARATUS

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[73] Assignee: Notetry Limited, Little Somerford, United Kingdom

[21] Appl. No.: 850,000

[22] PCT Filed: Dec. 20, 1995

[86] PCT No.: PCT/GB95/02987

§ 371 Date: Aug. 11, 1997

§ 102(e) Date: Aug. 11, 1997

[87] PCT Pub. No.: WO96/19294

PCT Pub. Date: Jun. 27, 1996

[30] Foreign Application Priority Data

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Mar. 7, 1995 [GB] United Kingdom 9504504

[51] Int. Cl.[6] B01D 45/12

[52] U.S. Cl. 55/337; 55/345; 55/429; 55/459.1; 55/DIG. 2; 55/DIG. 3

[58] Field of Search ..... 55/337, 345, 429, 55/459.1, DIG. 2, DIG. 3

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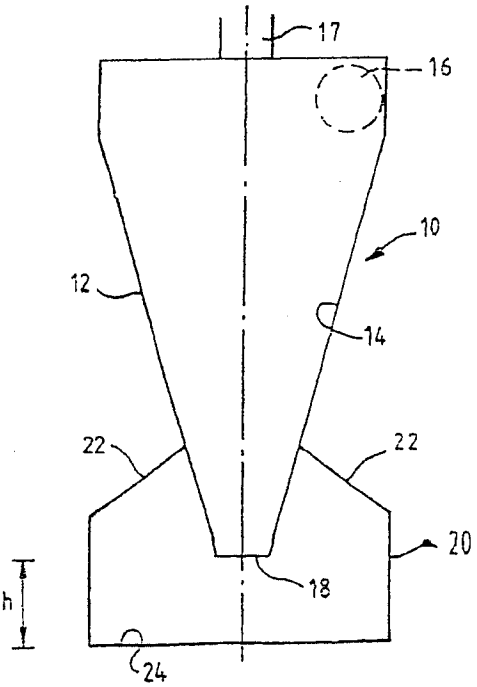
Primary Examiner—Jay H. Woo
Assistant Examiner—Minh-Chau T. Pham
Attorney, Agent, or Firm—Ian C. Mcleod

[57] ABSTRACT

An apparatus (10) for separating dirt or dust from an airflow comprising a frustoconical cyclone (12) having a tangential air inlet (16) located at or adjacent the end of the cyclone (12) having the larger diameter and a cone opening (18) located at the end of the cyclone (12) having the smaller diameter is described. A collector (20) is arranged so as to surround the cone opening (18) and has a base surface (24) facing towards the cone opening (18). The distance between the cone opening (18) and the base surface (24) is between 4 and 6 mm or between 45 and 60 mm. The apparatus (10) is reduced in size without substantially affecting the separation efficiency.

24 Claims, 4 Drawing Sheets



D121

FIG.1a

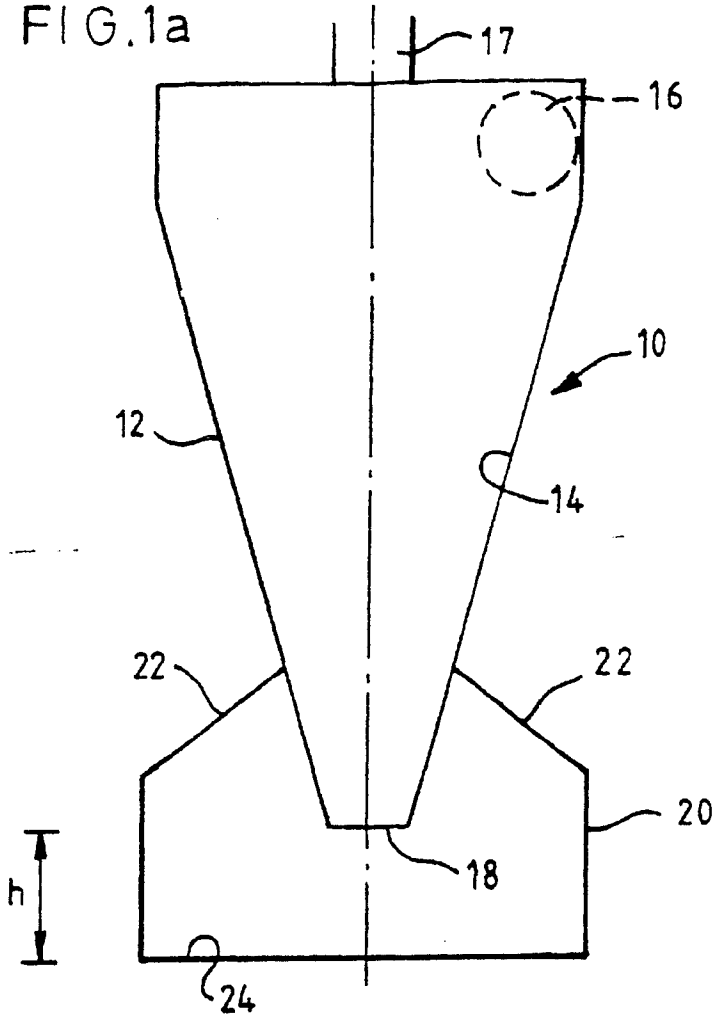


FIG.1b

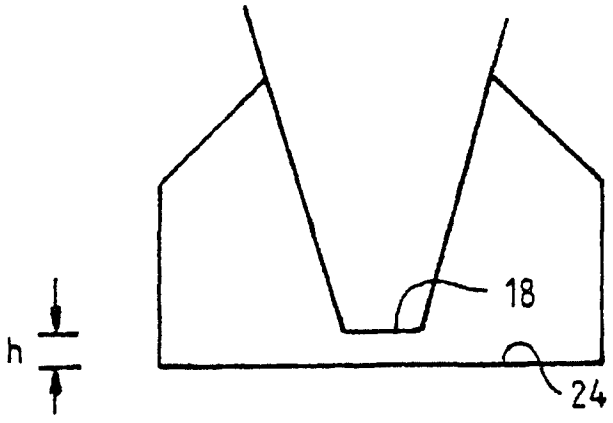
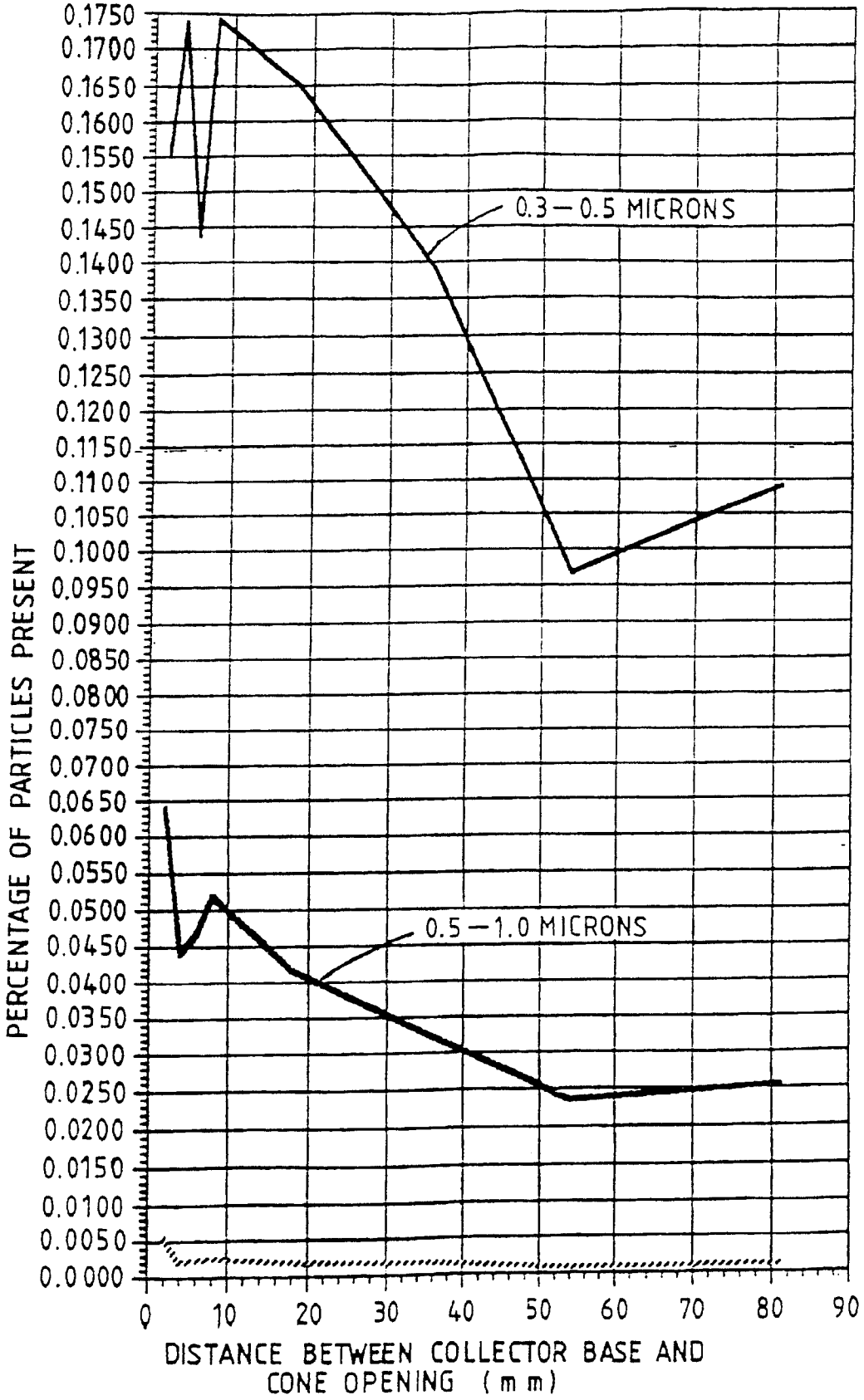


FIG. 2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0.0200
0.0150
0.0100
0.0050
0.0000
PERCENTAGE OF PARTICLES PRESENT
0.3 — 0.5 MICRONS
0.5 — 1.0 MICRONS
0
10
20
30
40
50
60
70
80
90
DISTANCE BETWEEN COLLECTOR BASE AND CONE OPENING (mm)

FIG.3a

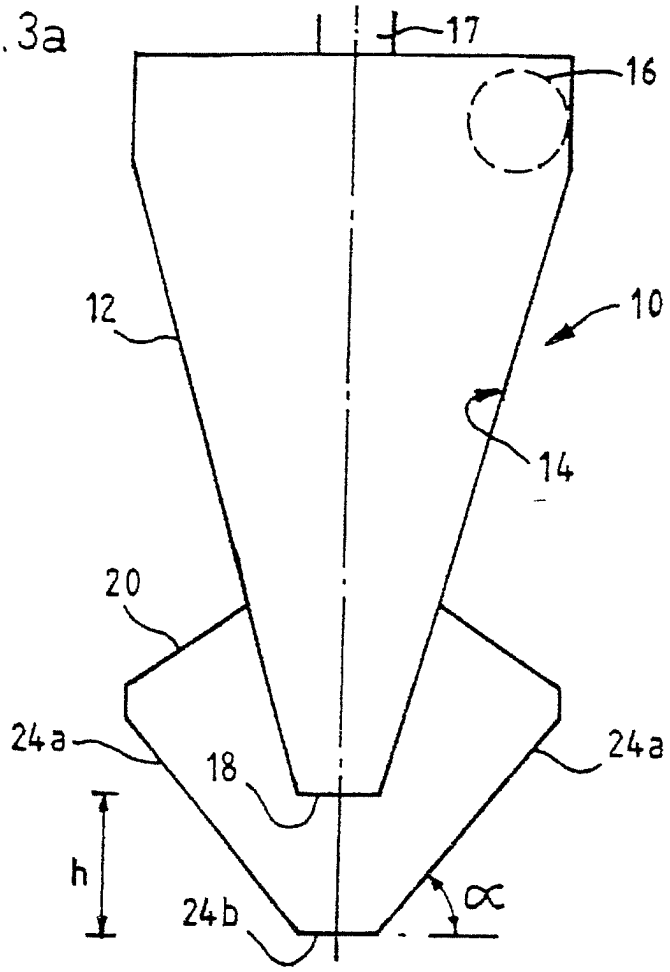


FIG.3b

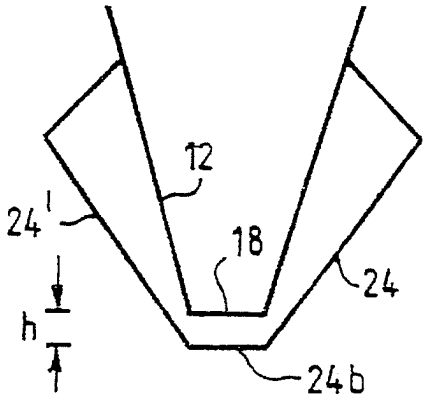


FIG.3c

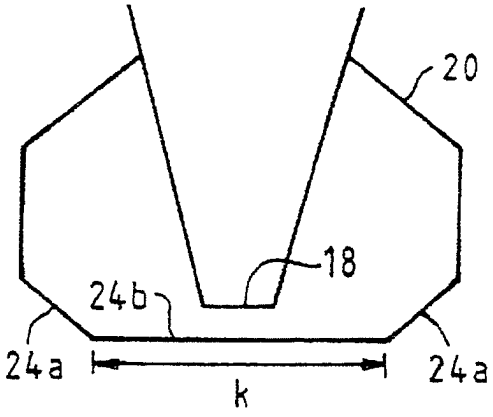


FIG. 4a

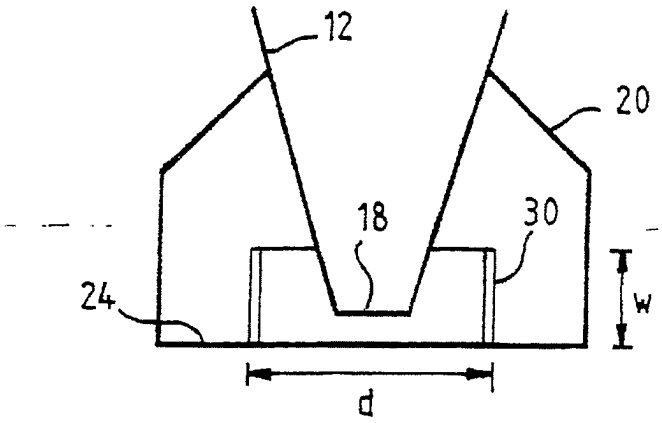
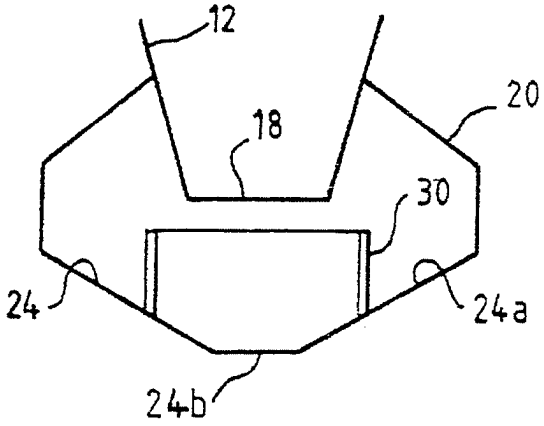


FIG. 4b



DUST SEPARATION APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to apparatus for separating dirt or dust particles from an airflow by cyclonic means. The invention relates particularly, but not exclusively, to cyclonic dust separation apparatus for use in a vacuum cleaner.

2. Description of Related Art

Cyclonic dust separation apparatus typically comprises a frusto-conical cyclone having a tangential air inlet at the end having the larger diameter and a cone opening leading to a dirt or dust collector at the end having the smaller diameter. The dust collector is generally cylindrical in shape and is considerably larger in diameter than the cone opening, normally having a diameter of at least three times that of the cone opening. In operation, an airflow carrying dirt and dust with it enters the cyclone via the air inlet and, by virtue of the tangential orientation of the air inlet, is set into a swirling motion over the interior surface of the cyclone. Most of the air of the airflow escapes from the cyclone by passing towards the longitudinal axis of the cyclone and exiting via an exit passage arranged substantially centrally of the end of the cyclone having the larger diameter. The remainder of the airflow spirals towards the cone opening at increasing angular speeds carrying the dirt and dust with it and is ejected into the dust collector, whereupon the dirt and dust particles are flung towards the cylindrical wall of the collector. The dirt and dust particles then collect in the lower regions of the cylindrical wall, whilst the remainder of the airflow exits from the collector via the cone opening and the exit passage. Apparatus of this type is illustrated and described in U.S. Pat. No. 5,090,976.

It is generally desirable for cyclonic dust separation apparatus to be relatively compact, particularly as regards the overall length of the apparatus, ie, the dimension parallel to the longitudinal axis of the cyclone. If the apparatus is used in a vacuum cleaner, compact dust separation apparatus reduces the overall dimensions of the complete cleaner and lowers the centre of gravity of the cleaner which, in turn, increases its stability. This is particularly advantageous in cylinder-type cleaners as well as upright-type vacuum cleaners.

OBJECTS

It is an object of the present invention to provide dust separation apparatus which is relatively compact without any significant loss of dust separation efficiency.

SUMMARY OF THE INVENTION

According to the invention, there is provided apparatus for separating dirt or dust from an airflow comprising a frustoconical cyclone having a tangential air inlet located at or adjacent the end of the cyclone having the larger diameter and a cone opening located at the end of the cyclone having a smaller diameter than at the end having the larger diameter, and a collector arranged so as to surround the cone opening and having a base surface facing towards the cone opening and upwardly ending wall, wherein the distance between the cone opening and the base surface is either between 4 and 6 mm or between 45 and 60 mm. Advantageous features are set out in the subsidiary claims.

It has previously been assumed that as large a distance as possible between the base surface and the cone opening is desirable. This allows more volume in the collector for separated dirt and dust to accumulate before emptying is required and was also thought to reduce the likelihood of separated dirt and dust becoming re-entrained into the airflow. The distance between the base surface and the cone opening has therefore been limited merely by the desired overall dimensions of the machine of which the dust separation apparatus forms part. However, it has now been found that varying this distance can affect the separation efficiency of the apparatus. Maxima of separation efficiency for different sizes of cyclone and collector occur when the distance between the base surface and the cone opening lies in the range 30 mm to 70 mm. A particularly advantageous distance is 54 mm. Surprisingly, a distance of less than 8 mm, particularly around 4 mm to 6 mm, is highly efficient even though it was initially thought that such a small distance would adversely affect the airflow in the cyclone and collector. Reducing the distance between the base surface and the cone opening to 8 mm or less therefore has an additionally advantageous effect on the overall dimensions of the apparatus without substantially detracting from the separation efficiency thereof. The centre of gravity of the separation apparatus is therefore lowered.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described with reference to the accompanying drawings, wherein:

FIG. 1*a* is a sectional side view of a first embodiment of apparatus for separating dirt or dust from an airflow according to the invention;

FIG. 1*b* is a sectional side view, corresponding to part of FIG. 1*a*, of a second embodiment of the invention;

FIG. 2 is a graph showing filtration efficiency test results for a 260 mm cyclone with a flat-bottomed fine dust collector at varying distances from the cone opening;

FIG. 3*a* is a sectional side view of a third embodiment of the invention;

FIGS. 3*b* and 3*c* are sectional side views, corresponding to part of FIG. 3*a*, of fourth and fifth embodiments respectively of the invention;

FIG. 4*a* is a sectional side view, corresponding to FIG. 1*b*, of a sixth embodiment of the invention; and

FIG. 4*b* is a sectional side view, corresponding generally to FIGS. 3*b* and 3*c*, of a seventh embodiment of the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. 1*a* shows apparatus 10 for separating dirt or dust from an airflow consisting of a frustoconical cyclone 12 having an interior surface 14. An air inlet 16 is arranged at the end of the cyclone 12 having the larger diameter and the air inlet 16 communicates with the cyclone 12 so as to introduce air tangentially into the cyclone 12.

At the end of the cyclone 12 having the smaller diameter, ie. remote from the air inlet 16, there is a cone opening 18. Surrounding the cone opening 18 and sealed against the outer walls of the cyclone 12 is a collector 20 for collecting dirt and dust separated from the airflow. The main body of the collector 20 is generally cylindrical in shape although inclined walls 22 extend between the generally cylindrical portion and the cyclone 12. The collector 20 has a base surface 24 facing towards the cone opening 18, ie. remote from the main body of the cyclone 12.

In use, an airflow consisting of a stream of air having dirt and dust particles entrained therein enters the cyclone 12 via

the inlet 16. Because of the tangential entry arrangement, the dirt-laden airflow takes up a swirling motion inside the cyclone 12 and spirals over the interior surface 14 of the cyclone 12 towards the cone opening 18 at ever-increasing angular speeds, with clean air escaping from the cyclone 12 by moving inwardly towards the longitudinal axis and upwardly towards an exit port 17. As soon as the remainder of the airflow enters the collector 20 via the cone opening 18, the dirt and dust particles entrained within the airflow are flung towards the side walls of the collector 20. The airflow, which is substantially free of dirt and dust particles, then exits the collector 20 via the cone opening 18 and leaves the cyclone 12 by means of the exit port 17 located substantially centrally of the end of the cyclone 12 having the larger diameter.

It has been found that, by varying the distance h between the base surface 24 and the cone opening 18, that the separation efficiency of the apparatus 10 can be improved. When the distance h is set at a value of between 30 mm and 70 mm, the separation efficiency increases. In particular, there is a peak in separation efficiency when the distance h is set at substantially 54 mm.

It has also been found that the separation efficiency is particularly good if the distance h is reduced to less than 10 mm. This is extremely surprising because it has previously been anticipated that such a small gap between the cone opening 18 and the base surface 24 would either restrict the airflow through the dirt or dust separation apparatus 10 or increase the likelihood of separated dirt or dust becoming re-entrained within the airflow. Tests have shown that this is not the case and that there is a particularly good separation efficiency when the distance h is between 4 mm and 6 mm. This arrangement is illustrated in FIG. 1*b*.

Test results showing the variation in separation efficiency for different distances between the base surface 24 and the cone opening 18 are shown in FIG. 2. The tests were carried out on apparatus incorporating a 260 mm cone and a flat-bottomed collector positioned at varying distances from the cone opening. The upper line shows the percentage of particles falling in the range 0.3–0.5 μm present in the airflow after a standard test time, and the lower line shows the percentage of particles falling in the range 0.5–1.0 μm present after the standard test time. Clear minima can be seen at distances of 4 mm–6 mm and 54 mm.

FIGS. 3*a*, 3*b* and 3*c* illustrate alternative embodiments of the first aspect of the invention. The apparatus shown in FIG. 3*a* corresponds closely to the apparatus shown in FIG. 1*a*. The only difference between the apparatus shown in FIGS. 1*a* and 3*a* is the shape of the collector 20. In FIG. 3*a*, the planar base surface 24 is replaced by a base surface 24' consisting of a frustoconical portion 24*a* surrounding a planar circular portion 24*b*. (The cylindrical portions of the collector 20 shown in FIG. 1*a* have also been reduced in height.) The result is that the collector 20 shown in FIG. 3*a* is substantially frustoconical in shape. This allows the entire apparatus 10 to be rotated about an axis running along any diameter of the central portion 24*b* so as to tilt the apparatus 10 with respect to a fixed surface parallel to that axis.

It had previously been expected that dirt and dust separated from the airflow on entry into the collector 20 via the cone opening 18 would travel down the inclined surfaces 24*a* of the collector 20 and accumulate in the region of the central portion 24*b*. It was thought that such an accumulation would result in the separated dirt and dust being re-entrained into the airflow. However, tests have shown that this re-entrainment does not occur.

In the embodiment shown in FIG. 3*a*, the distance between the cone opening 18 and the central portion 24*b* of the base surface 24' is substantially 54 mm. Furthermore, the angle of inclination α of the frusto-conical portion 24*a* with respect to the central portion 24*b* is substantially 50°. Also, the diameter of the central portion 24*b* is substantially identical to the diameter of the cone opening 18 and this is preferably substantially 25 mm.

Various modifications and variations are possible within the context of this aspect of the invention: the distance between the cone opening 18 and the central portion 24*b* of the base surface 24' can be varied and, in particular, can be reduced to a distance of substantially 7 mm. This spacing gives an increased separation efficiency. Such an arrangement is illustrated in FIG. 3*b*.

A further alternative arrangement is illustrated in FIG. 3*c* which shows the collector 20 having a frustoconical portion 24*a* and a central circular portion 24*b*, but wherein the central circular portion 24*b* has a diameter k which is substantially larger than that of the cone opening 18. In the embodiment shown in FIG. 3*c*, the diameter of the cone opening 18 is substantially 25 mm, whereas the diameter of the circular central portion 24*b* is substantially 125 mm.

FIGS. 4*a* and 4*b* illustrate an additional measure designed to reduce any possibility of dirt and dust collected in the collector 20 becoming re-entrained in the airflow circulating in the apparatus 10. This measure applies primarily in cases wherein the distance between the cone opening 18 and the base surface 24 is less than 8 mm or wherein the base surface 24 is conical or frusto-conical in shape.

In order to reduce still further the possibility of dirt and dust located in the collector 20 from being re-entrained into the airflow, dirt and dust-retaining means in the form of a wall 30 are provided on the base surface 24. The wall 30 is upwardly extending with respect to the base surface 24 and is substantially annular in shape, although other plan shapes could be utilised. The diameter d of the annular wall 30 is substantially 70 mm but this could be varied within the range 30 mm to 100 mm. The height w of the wall 30 is substantially 55 mm from the junction between the wall 30 and the base surface 24 but could be varied within the range 20 mm to 60 mm.

The wall 30 has a tapering cross-section as shown in FIG. 4*a*. The thickness of the wall 30 is greater at the end thereof adjacent the junction with the base surface 24 than at the distal end. The upper end of the wall 30 is radiused to form a smooth finish.

When the annular wall 30 is provided in conjunction with a frustoconical base surface 24 as shown in FIG. 4*b*, the junction between the wall 30 and the base surface 24 is on the frustoconical portion 24*a* of the base surface 24. However, if the central portion 24*b* is sufficiently large in diameter, the junction between the wall 30 and the base surface 24 can occur in the central planar portion 24*b*.

In operation, air exiting the cyclone 12 via the cone opening 18 causes dirt and dust particles entrained therein to be flung against the outer walls of the collector 20. The annular wall 30 prevents the dirt and dust particles from travelling towards the central portion of the base surface 24 and thereby reduces the possibility of dirt and dust particles becoming re-entrained into the airflow.

It is envisaged that cyclonic dust separation apparatus as described above can be used to advantage in a number of different situations. The application to which it is envisaged that the present invention is most likely to be applied is that of vacuum cleaning apparatus. Either of the aspects of the

invention described above can be used in an upright or cylinder-type vacuum cleaner in order to lower the centre of gravity and/or reduce the size of the apparatus as a whole. It is also likely that the apparatus described above will be used in conjunction with further cyclonic dust separation apparatus specifically designed to remove larger dust and fluff particles in a so-called "low efficiency" cyclone. The apparatus described above will therefore be intended to remove only the finer particles of dirt and dust entrained in the airflow.

However, it is also envisaged that the invention described above may well be utilised in other situations, for example the removal or dirt and dust particles from internal combustion engine emissions. The principles described above are equally applicable to such situations and need not be used in combination with further cyclonic separation apparatus unless it is so desired.

We claim:

1. Vacuum cleaner apparatus for separating dirt or dust from an airflow comprising a frustoconical cyclone having a tangential air inlet located at or adjacent the end of the cyclone having the larger diameter and a cone opening located at the end of the cyclone having a smaller diameter than at the end having the larger diameter, and a collector arranged so as to surround the cone opening and having a base surface facing towards the cone opening, wherein the distance between the cone opening and the base surface is either less than 8 mm or between 30 mm and 70 mm such that there is improved separation of the dirt or dust because of the distance in the apparatus.

2. Apparatus as claimed in claim 1, wherein the base surface is substantially planar.

3. Apparatus as claimed in claim 2, wherein the distance between the cone opening and the base surface is measured parallel to a longitudinal axis between the ends of the cyclone.

4. Apparatus as claimed in claim 3, wherein the distance between the cone opening and the base surface is between 4 mm and 6 mm.

5. Apparatus as claimed in claim 3, wherein the distance between the cone opening and the base surface is between 45 mm and 60 mm.

6. Apparatus as claimed in claim 5, wherein the distance between the cone opening and the base surface is 54 mm.

7. Apparatus as claimed in any one of claims 3, 4, 5 or 6, wherein the base surface has a diameter which is spaced around a longitudinal axis of the cyclone.

8. Apparatus as claimed in claim 7, wherein the an upwardly-extending wall is annular.

9. Apparatus as claimed in claim 8, wherein an upwardly extending wall extends upwardly from the base surface for between 10 mm and 60 mm.

10. Apparatus as claimed in claim 9, wherein the wall extends upwardly from the base surface for 55 mm.

11. Apparatus as claimed in any one of claims 3, 4, 5 or 6, wherein the base surface has a diameter spaced around the longitudinal axis of the cyclone and wherein the diameter of the wall is between 30 mm and 100 mm.

12. Apparatus as claimed in claim 11, wherein the diameter of the wall is 70 mm.

13. Apparatus as claimed in any one of claims 3, 4, 5 or 6, wherein the base surface has a diameter spaced around the longitudinal axis of the cyclone with an upwardly extending annular wall from the base surface wherein a diameter of the wall is greater at an end adjacent the base surface than at an end remote therefrom.

14. Apparatus as claimed in any one of claims 3, 4, 5 or 6, wherein the base surface is spaced around the longitudinal axis of the cyclone with an upwardly extending annular wall from the base surface wherein the end of the wall remote from the base surface is radiused.

15. Apparatus as claimed in any one of claims 3, 4, 5 or 6, wherein the base surface has a diameter spaced around the longitudinal axis of the cyclone with an upwardly extending annular wall from the base surface wherein at least a portion of the annular wall is conical or frustoconical in shape.

16. Apparatus as claimed in claim 15, wherein the collector comprises a frustoconical portion as the wall and a circular portion as the base portion.

17. Apparatus as claimed in claim 16, wherein the diameter of the circular portion is the same as that of the cone opening.

18. Apparatus as claimed in claim 16 or 17, wherein the diameter of the circular portion is between 20 mm and 30 mm.

19. Apparatus as claimed in claim 16, wherein the diameter of the circular portion is 25 mm.

20. Apparatus as claimed in claim 16, wherein the diameter of the circular portion is greater than a diameter of the cone opening.

21. Apparatus as claimed in claim 20, wherein the diameter of the circular portion is 125 mm.

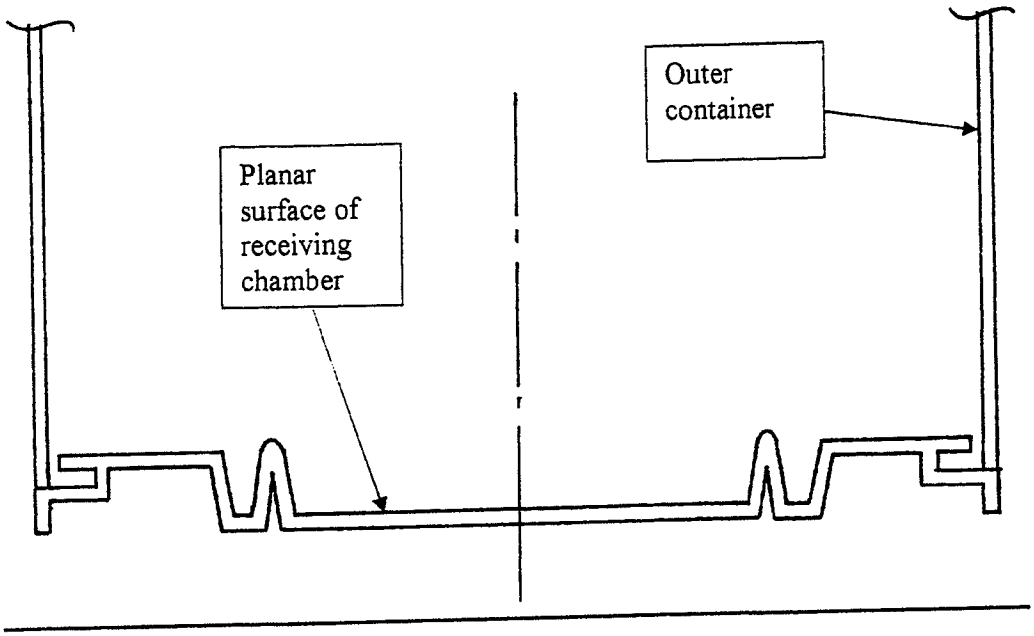
22. Apparatus as claimed in claim 16, wherein the circular portion is planar.

23. Apparatus as claimed in claim 15, wherein the conical or frusto-conical portion of the collector is inclined at an angle of between 30° and 50° to the longitudinal axis of the cyclone.

24. Apparatus as claimed in claim 23, wherein the conical or frusto-conical portion of the base surface is inclined at an angle of 40° to the longitudinal axis of the cyclone.

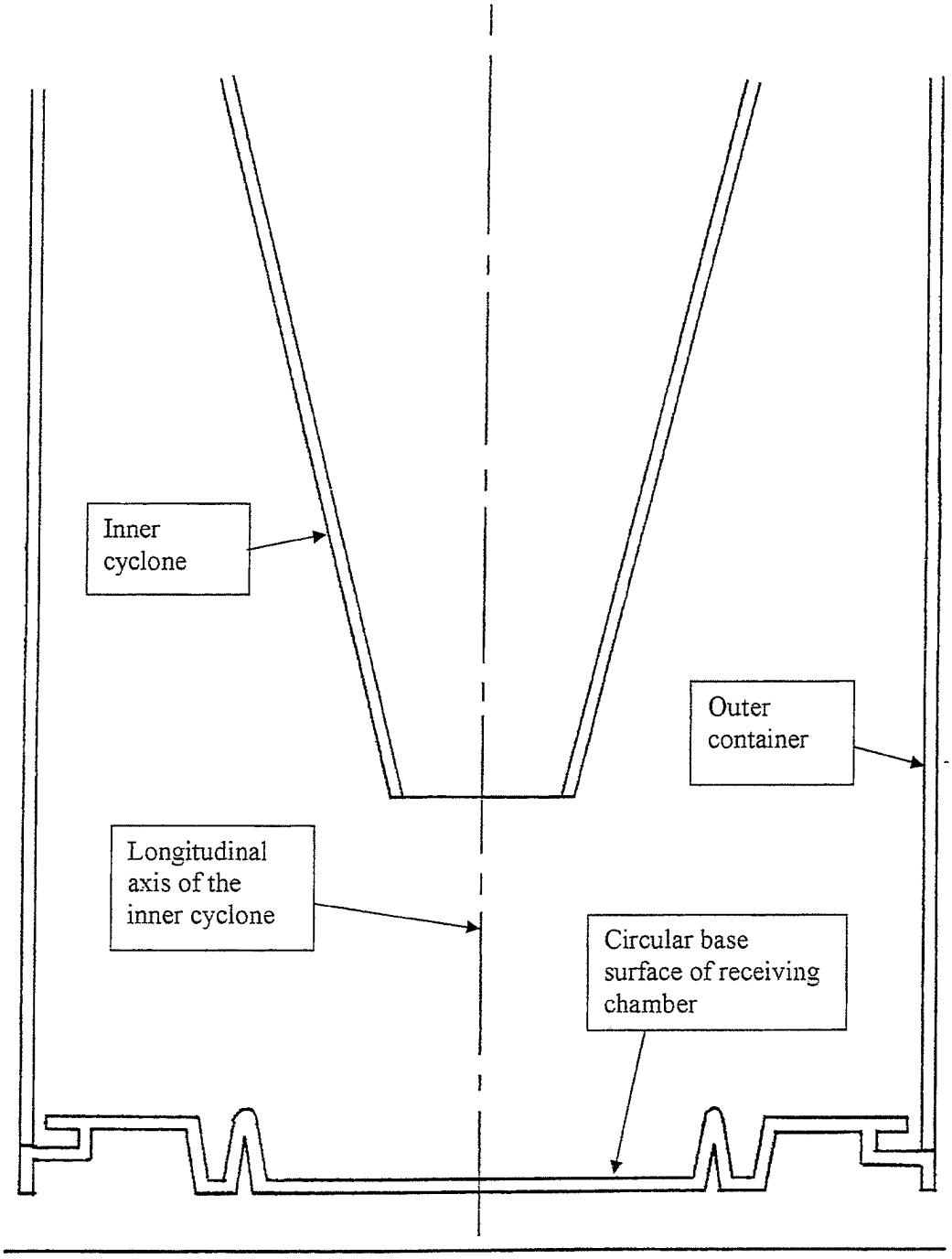
* * * * *

Exhibit 27 – Diagram illustrating the planar nature of the base surface of the Hoover Fusion



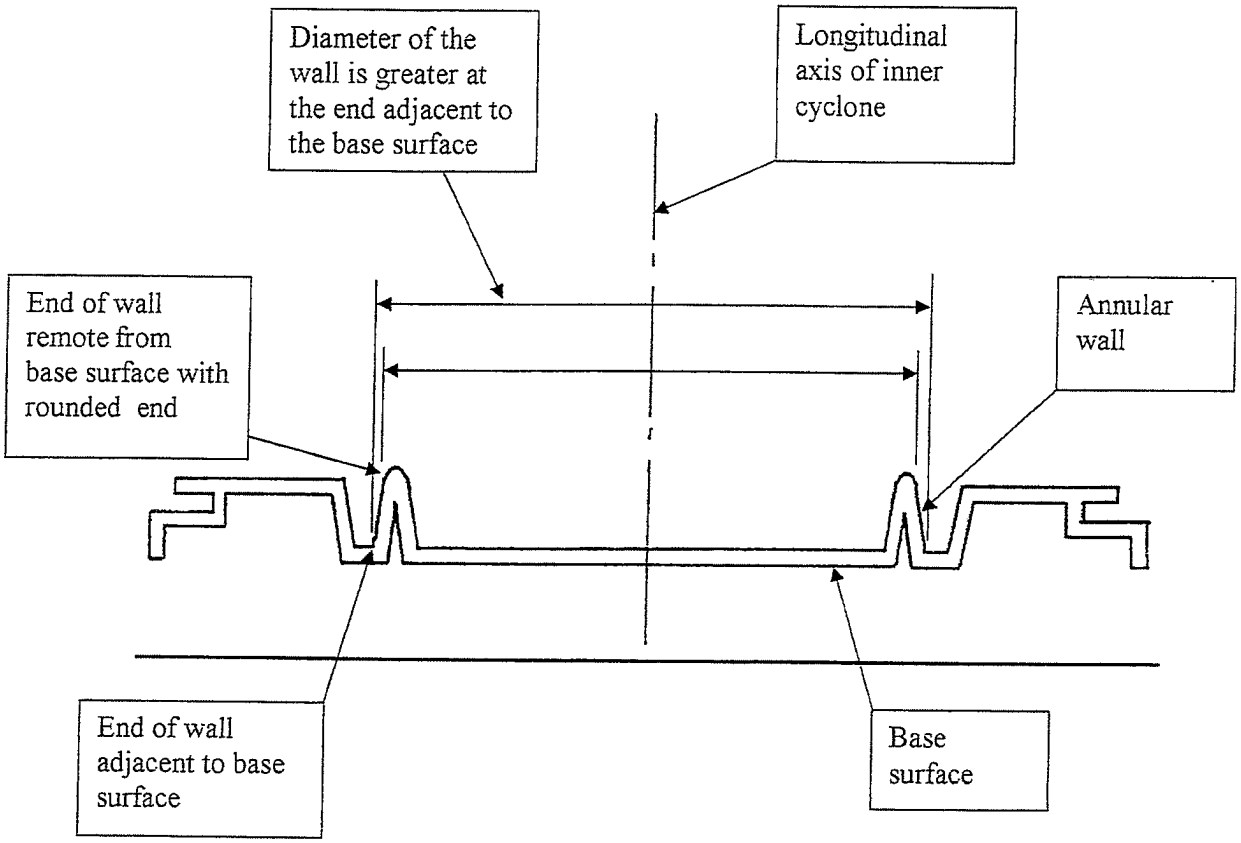
Note - schematic drawing, not to scale

Exhibit 28 – Diagram illustrating the relative position of the longitudinal axis of the inner cyclone and the base surface of the Hoover Fusion



Note – schematic drawing only, not to scale. Other components omitted for clarity

Exhibit 29 – Diagram illustrating annular wall from base surface of receiving chamber of the Hoover Fusion



Note - schematic drawing, not to scale

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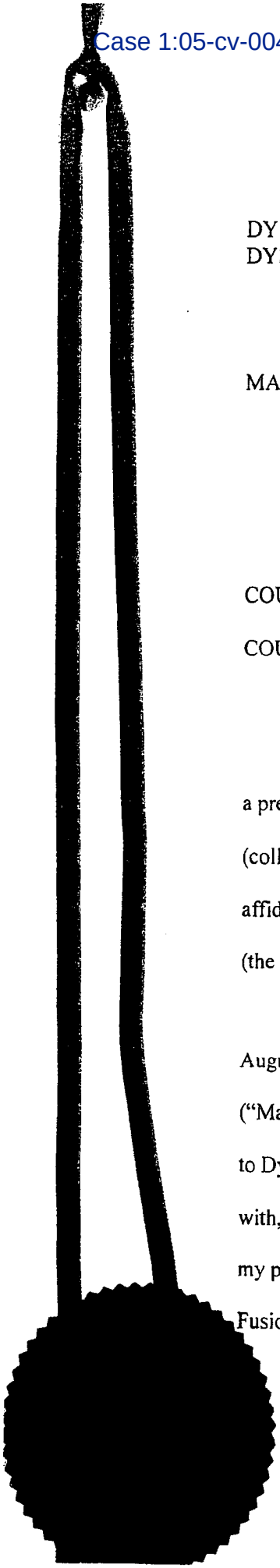

IN THE UNITED STATES DISTRICT COURT

FOR THE DISTRICT OF DELAWARE

DYSON TECHNOLOGY LIMITED and DYSON, INC., Plaintiffs, v. MAYTAG CORPORATION, Defendant.	)	C.A. No. 05-434 (GMS)

REPLY AFFIDAVIT OF GARETH EVAN LYN JONES

COUNTRY OF ENGLAND)
: ss.
COUNTY OF WILTSHIRE)

GARETH EVAN LYN JONES, being duly sworn, deposes and says:

1. I submit this reply affidavit in further support of the motion for a preliminary injunction brought by Dyson, Inc. and Dyson Technology Limited (collectively, "Dyson"). Unless otherwise specified, the capitalized terms used in this affidavit shall have the meanings ascribed to them in my affidavit of 25 July, 2005 (the "Jones Aff."), which I am informed was filed with the Court on 29 July, 2005.

2. I have received the Affidavit of Charles D. DeGraff, dated 25 August, 2005 (the "DeGraff Aff."), which I am informed Maytag Corporation ("Maytag") has submitted to the Court, along with certain other papers, in opposition to Dyson's motion for a preliminary injunction. Mr. DeGraff does not take issue with, and apparently agrees with, the vast majority of the opinions expressed by me in my prior affidavit and, with two exceptions, does not dispute that Maytag's Hoover Fusion has the separate elements of various dependent claims of the patents-in-suit.

Rather, he attempts to show the absence of a small number of elements necessary to establish Maytag's infringement of the Patents in Suit. It is my opinion that assertions by Mr. DeGraff in his affidavit purporting to show the absence of these elements are without merit. I continue to conclude that the Hoover Fusion infringes claim no. 14 of the '515 Patent; claim nos. 15, 16 and 17 of the '748 Patent; claim nos. 1, 2, 3, 7, 11, 23, 24 and 25 of the '008 Patent; and claim nos. 1, 2, 3, 7, 13 and 14 of the '038 Patent.

3. As was the case in my prior affidavit, I have interpreted the various claim elements discussed below as one of ordinary skill in the art of cyclonic vacuum cleaner technology would interpret them in light of the patent specifications. The photographs of the Hoover Fusion or its parts referenced below and attached as exhibits to this affidavit were taken by me using a digital camera that I own.

Certain Observations on "Measurements" in the DeGraff Affidavit

4. Before beginning my analysis, I note that in his affidavit, Mr. DeGraff refers in several places to certain measurements of Hoover Fusion parts. See, e.g., DeGraff Aff. ¶ 8 (distance of dirty air inlet from top of container), ¶ 15 (diameter of plastic portion of dirt receiving chamber), ¶ 16 (diameter of "ring area" at the bottom of the outer container), ¶ 31 (location of plastic component containing shroud in relation to air inlet of inner cyclone), ¶ 33 (distance of perforations from bottom of shroud), and ¶ 39 (distance between cone opening and base surface).

5. I find these measurements to be inherently suspect for two reasons. First, it is peculiar that Mr. DeGraff would need to "measure" anything at all on a Hoover Fusion. Presumably Maytag has product specifications and drawings that elaborate on the size, shape and location of parts to be used in the manufacturing

of the Hoover Fusion, and Mr. DeGraff should have referred to those specifications and drawings in his affidavit. I relied exclusively on measurements taken from Hoover Fusions in my affidavit because I did not have access to product specifications and drawings. Second, there is no elaboration whatsoever in the DeGraff Affidavit on the process used to determine these measurements. Mr. DeGraff does not say how many machines were used to obtain the measurements, where these machines came from, who took the measurements, what instruments were used to do the measuring, what exactly was measured (for example, were measurements taken from the top, center or bottom portion of a part), and what the measurement represents (for example, were any or all of the measurements from a single location (or device) or an "average" of several measurements from different locations (or devices)). One might infer that Mr. DeGraff did not himself conduct these measurements and does not know how they were conducted.

The '515 Patent

Claim No. 14 of the '515 Patent

6. In his affidavit, Mr. DeGraff asserts that four of the elements of claim no. 14 of the '515 Patent are absent from the Hoover Fusion. These assertions are not, in my view, correct.

7. First, Mr. DeGraff contends that the Hoover Fusion's dirty air inlet is not "at an upper portion of the outer container" as required by the claim. (See discussion of Element 14.2 in the Jones Affidavit (¶ 21)). He reaches this conclusion based on (a) his finding that the words "upper portion" must mean "top" of the outer container because that is where the dirty air inlet is located in Figure 1 of the '515 Patent and (b) his finding that the Hoover Fusion's dirty air inlet is not at the "top" of

the outer container, but "is positioned 41% of the distance from the top of the outer container." (DeGraff Aff. ¶ 8). He is wrong in both respects. A person skilled in the art of cyclonic vacuum cleaner technology would interpret the words "upper portion of the outer container" as used here to mean that the dirty air inlet must be above the midline of the outer container—which Mr. DeGraff concedes is the case here—and not to mean that the dirty air inlet must be at the "top" of the outer container. Indeed, the patent elsewhere refers to the "top" of the outer container (see col. 6, l. 8). Had the patent intended that the dirty air inlet be located at or near the "top" of the outer container, as suggested by Mr. DeGraff, it would have used the word "top" in the claim element as it did elsewhere in the patent.

8. Moreover, the dirty air inlet on the Hoover Fusion is closer to the "top" of the outer container than Mr. DeGraff states. A person skilled in the art of cyclonic technology would understand that the purpose of the outer container is to enclose a volume. Thus the "top" of the container is the uppermost portion of the container that holds a volume. On the Hoover Fusion, this point is where the rubber seal on the component containing the shroud touches the inner surface of the container and encloses the volume in the container. The location of this component is shown in the photographs attached as Exhibit 30. Using a steel ruler, I have determined that the center of the dirty air inlet on the Hoover Fusion is only about 30.7% from this point.

9. Second, Mr. DeGraff states that the Hoover Fusion's dirty air inlet is not "oriented for supplying dirt laden air into the container tangentially to the interior surface of the outer container" (see discussion of Element 14.3 in the Jones Affidavit (¶¶ 22-23)) because it does not "cause" the air to flow tangentially into the

interior surface of the container. (DeGraff Aff. ¶¶ 9-10). There is no merit to this statement because the claim element on its face requires only that the dirty air inlet be "oriented" for supplying tangential air flow, it does not require that the inlet "cause" the tangential airflow. As I explained in my prior affidavit, a person skilled in the art of cyclonic vacuum cleaner technology would understand this claim element to require that the dirty air inlet be configured to allow dirt laden air sucked up by the vacuum cleaner to flow into the container tangentially to the interior surface of the outer container. (Jones Aff. ¶ 22). The dirty air inlet of the Hoover Fusion is configured to serve this function. (Jones Aff. ¶¶ 22-23). Photographs of the Hoover Fusion's dirty air inlet are attached as Exhibit 31. As can be seen from the photographs, the dirty air inlet has a tear-drop shape that, when viewed from the side, creates a circular opening allowing for tangential air flow to the interior surface of the outer container. The sole purpose of this shape is to allow air to flow tangentially to the interior surface of the outer container, and Mr. DeGraff does not dispute this.

10. Third, Mr. DeGraff asserts that the Hoover Fusion does not have a "cyclone for receiving an air flow from the air inlet and for maintaining its velocity to a cone opening" (see discussion of Element 14.8 in the Jones Affidavit (¶ 28)) because, in his words, "the Fusion vacuum cleaner does not maintain the velocity of the air, but accelerates it." (DeGraff Aff. ¶¶ 11-12). This interpretation of the words "maintaining its velocity" is incorrect here. As I explained in my prior affidavit, a person skilled in the art of cyclonic vacuum cleaner technology would understand that the words "maintaining its velocity" as used in the claim element to mean that the conical shape of the cyclone assists in keeping the air flow moving as it makes its way from the air inlet at the top of the cyclone to the smaller opening at the

bottom of the cyclone. These words do not require that the air flow remain at a constant speed. Indeed, such an interpretation in the context of this patent—or any of the Patents in Suit for that matter—makes no sense because it is a recognized principle of cyclonic technology that air entering the top of a cone-shaped cyclone tangentially will continue to rotate (and accelerate) to the bottom of the cyclone. It is the acceleration that creates the centrifugal force necessary to separate finer dust particles from the air. The air accelerates when it flows through the inner cyclone of the preferred embodiments of every one of the Patents in Suit. If Mr. DeGraff is correct, as a practical matter, this claim could never be infringed.

11. Lastly, at ¶¶ 14-17 of his affidavit, Mr. DeGraff contends that the diameter at the end of the Hoover Fusion's dirt receiving chamber furthest from the cone opening is not a minimum of 3 times the diameter of the cone opening, as required by claim no. 14 of the '515 Patent. This contention also is erroneous. As I indicated in my prior affidavit, the diameter of the dirt collection chamber furthest from the cone opening is that located on the rubber-like portion of the chamber that touches the bottom of the container, and that diameter is about 3.11 times the diameter of the cone opening. (Jones Aff. ¶ 34). Mr. DeGraff claims that this rubber-like portion of the dirt collection chamber is not a portion of the dirt collection chamber at all, but is a separate part of the Hoover Fusion that acts as the "ring seal." But the rubber-like material is actually glued to the plastic portion of the dirt collection chamber—forming one component that is not separate or intended to be separable. A photograph of the dirt collection chamber on the Hoover Fusion is attached as Exhibit 15 to my prior affidavit. The fact that this portion of the dirt collection chamber may also perform the function of a ring seal is irrelevant to this claim element. In addition,

as noted in my prior affidavit, even if the relevant diameter of the receiving chamber is viewed as the end of the plastic portion of the chamber—and not the rubber-like extension—that diameter is still 2.97 times the diameter of the cone opening, which rounded to the nearest tenth is still 3 times the diameter of the cone opening. I note that Mr. DeGraff found that this diameter was "2.9 times the diameter of the cone opening." (DeGraff Aff. ¶ 15) Because Mr. DeGraff only carried out his calculation one decimal place, and not two decimal places, it is unclear if his measurement truly differs from mine. If there is a difference, it may be attributable to the methodology and equipment employed by the measurer. My measurements were based on averages of several measurements of the diameters at issue. (Jones Aff. ¶ 34). Mr. DeGraff—or whomever actually conducted the measurement for Maytag—may only have taken one measurement. In addition, I used sophisticated equipment—including a shadowgraph and a coordinate measuring machine (CMM)—to obtain precise measurements. The measurement in the DeGraff Affidavit may have been obtained using equipment that provides less precise measurements.

12. For the reasons expressed above and in my prior affidavit (see Jones Aff. ¶¶ 19-39), therefore, it continues to be my opinion that the Hoover Fusion infringes claim no. 14 of the '515 Patent.

The '748 Patent

Claim No. 15 of the '748 Patent

13. Mr. DeGraff also contends that four of the required elements of claim no. 15 of the '748 Patent are missing in the Hoover Fusion. (DeGraff Aff. ¶ 18). I disagree with this contention.